

Uncertainty of Passive Imager Cloud Optical Property Retrievals to Instrument Radiometry and Model Assumptions: Examples from MODIS

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A44B-05

AGU Fall Meeting
12 Dec 2013
San Francisco, CA

Outline

1. MODIS Solar Reflectance Optical Property Retrievals and Uncertainties

- challenge: choosing a subset of error sources that can be quantified and are operationally viable

2. Pixel-Level Uncertainties: MODIS Level-2 Example

3. Uncertainties in Aggregated Means: MODIS Level-3 Example

MODIS Collection 6 Cloud Retrieval (MOD06)

Error Sources Explicitly Included in Collection 6 Uncertainty Calculations

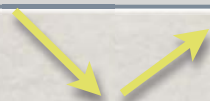


MODIS

- *instrument calibration (pixel-level, L1B file)*
- *atmospheric corrections: q (fwd. model LUT), O_3*

cloud retrievals (1 km): COT,
CER_1.6, CER_2.1, CER_3.7, CER_1.6/2.1
WP_1.6, WP_2.1, WP_3.7, WP_1.6/2.1

- *cloud model: droplet size distribution v_{eff}*



surface spectral reflectance/emission

Plane-Parallel Fwd. Model

- *Surface reflectance –*
Ocean: Cox-Munk wind speed/direction
Land: MODIS-derived gap-filled product
Snow/ice: MODIS-derived gap-filled database

- *3.7 μm retrievals: T_{sfc} , low cloud T_c retrievals, F_0*

cloud masking, cloud-top pressure provided
through separate algorithm team
(S. Ackerman et al.)

MODIS Collection 6 Cloud Retrieval (MOD06)

Error Sources NOT Explicitly Included in Collection 6 Uncertainty Calculations



MODIS

- *long-term radiometric bias/drift*
- *above-cloud aerosol [added later, not in original talk]*

cloud retrievals (1 km): COT,
CER_1.6, CER_2.1, CER_3.7, CER_1.6/2.1
WP_1.6, WP_2.1, WP_3.7, WP_1.6/2.1

- *cloud model: vertical and horizontal heterogeneity (3-D radiative effects)*



*More egregious cases accounted for by
flagging obvious partly cloudy pixels*

surface spectral reflectance/emission

Plane-Parallel Fwd. Model

cloud masking, cloud-top pressure provided
through separate algorithm team
(S. Ackerman et al.)

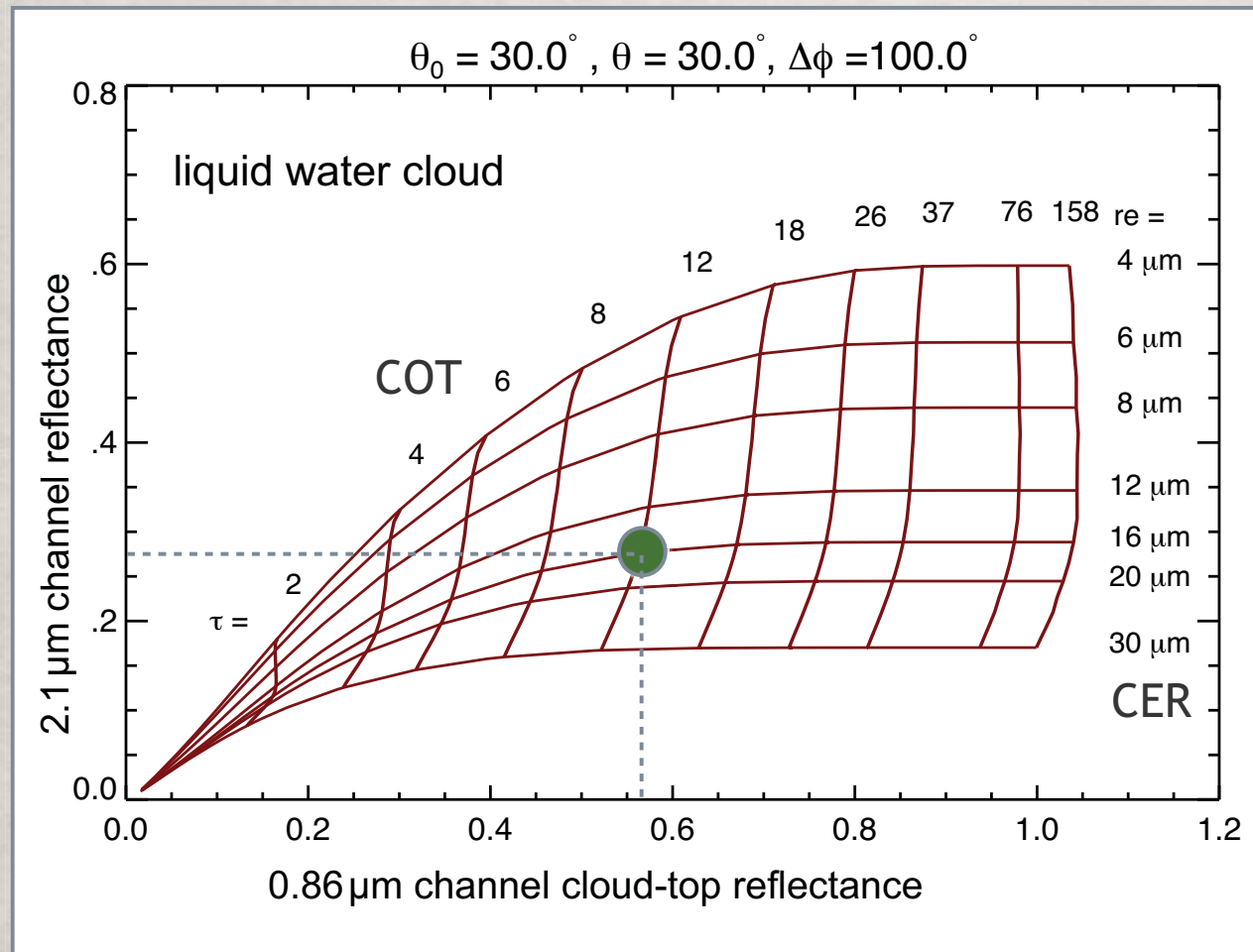
Other Error Sources Not Accounted for: Discrete Choices

- What is a cloud? What constitutes a cloudy FOV appropriate for a retrieval? [A44-03, *Ackerman et al.*]
- How to account for thermodynamic phase retrieval uncertainty?
- Choice of forward radiative cloud model (e.g., ice radiative models [A44B-07, *van Diedenhoven et al.*])?
- How to use Quality Assessment assignments (common in EOS and other products) or related information.
 - multiphase/multilayer scenes (MODIS has a multilayer flag)?
 - accounting for discrepancies from different spectral channel pairs? [A44B-08, *Zhang et al.*]

Subjectivity always comes into play. Sometime's it's explicit (developer says "I am making a subjective choice"), sometimes it's implicit.

Example MODIS Cloud Optical Thickness (COT) & Effective Radius (CER) Retrieval Solution Space

0.86 & 2.1 μm channel retrieval combination



retrieval error covariance

$$\left(\mathbf{K}^T \mathbf{S}_y^{-1} \mathbf{K}\right)^{-1} \text{ refl. meas. unc.}$$

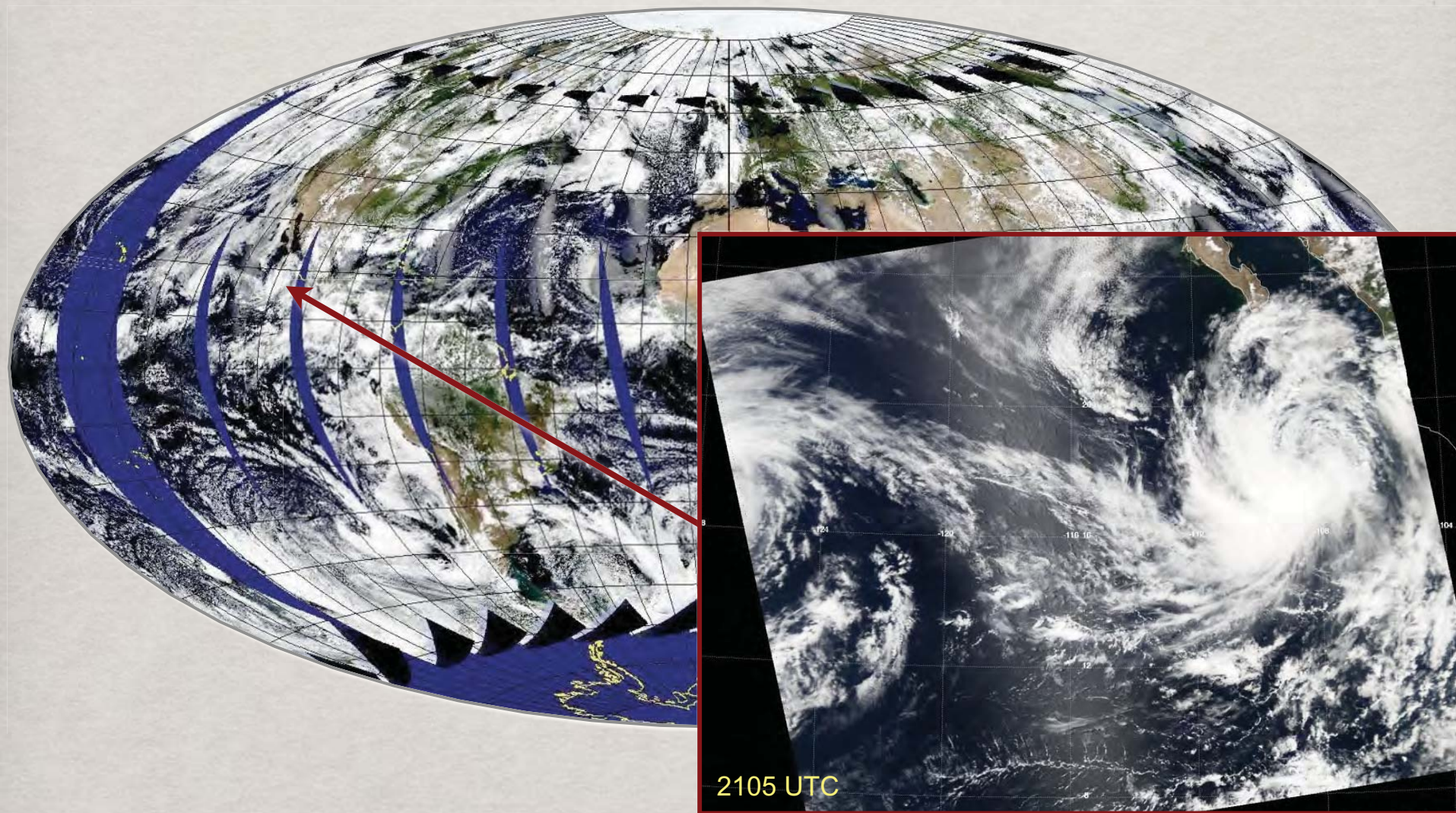
$$+ \left(\mathbf{K}^{-1} \mathbf{K}_b\right) \mathbf{S}_b \left(\mathbf{K}^{-1} \mathbf{K}_b\right)^T$$

*maps model uncertainty
into cloud-top reflect.
uncertainty*

Pt. 2

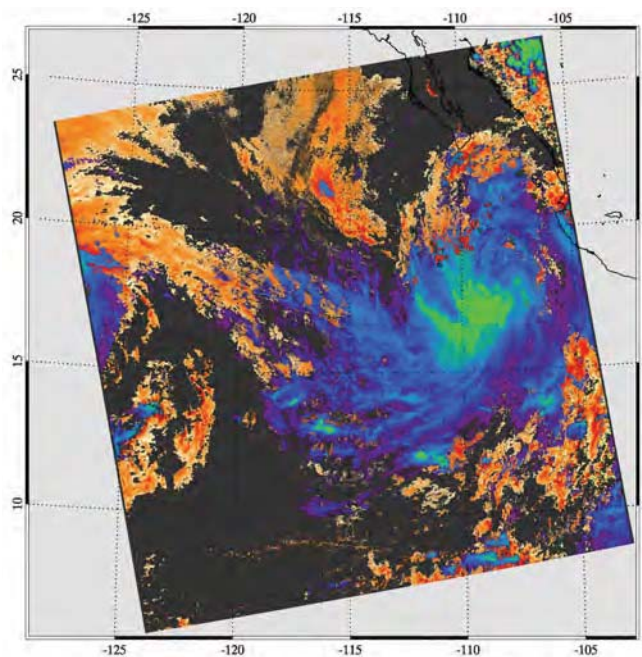
Pixel-Level Uncertainty Example

2 July 2008, MODIS Aqua

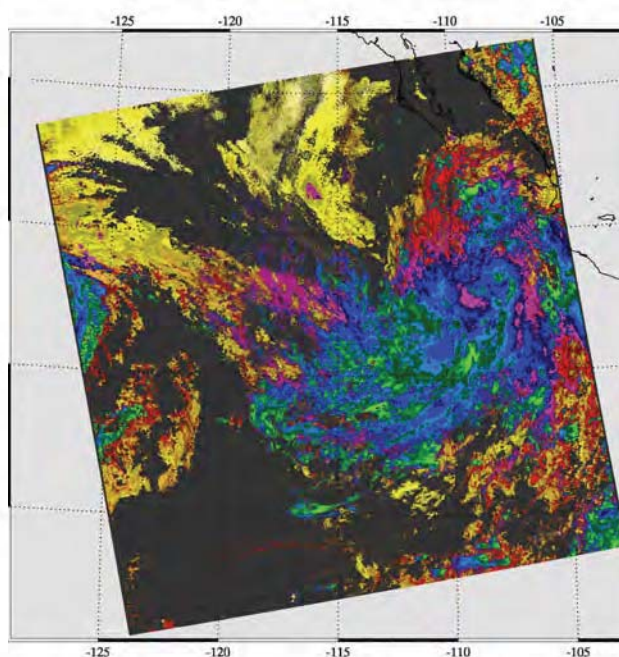
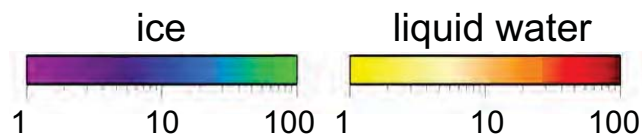


Pixel-Level Retrievals

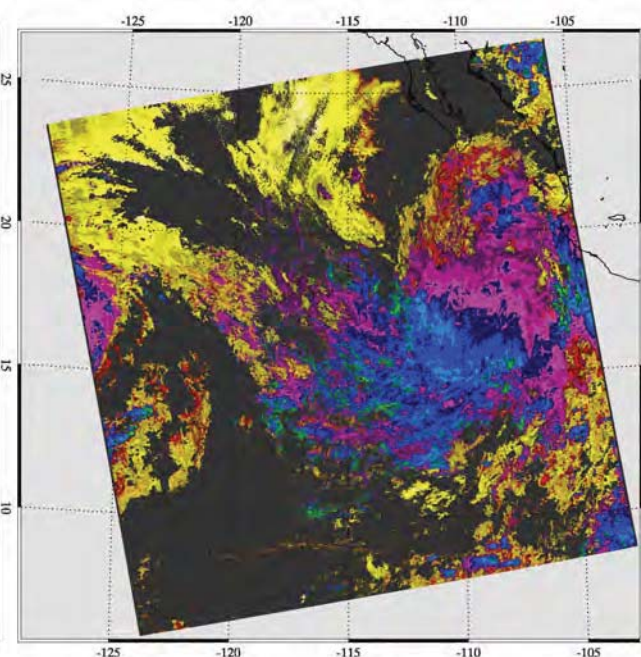
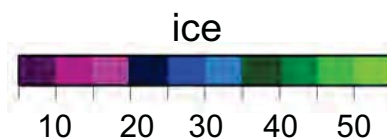
2 July 2008, MODIS Aqua C6, 2105 UTC
(best quality pixels only, CSR=0)



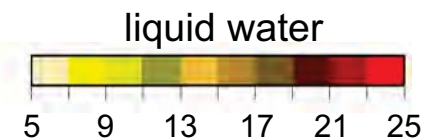
COT



CER_2.1 (μm)

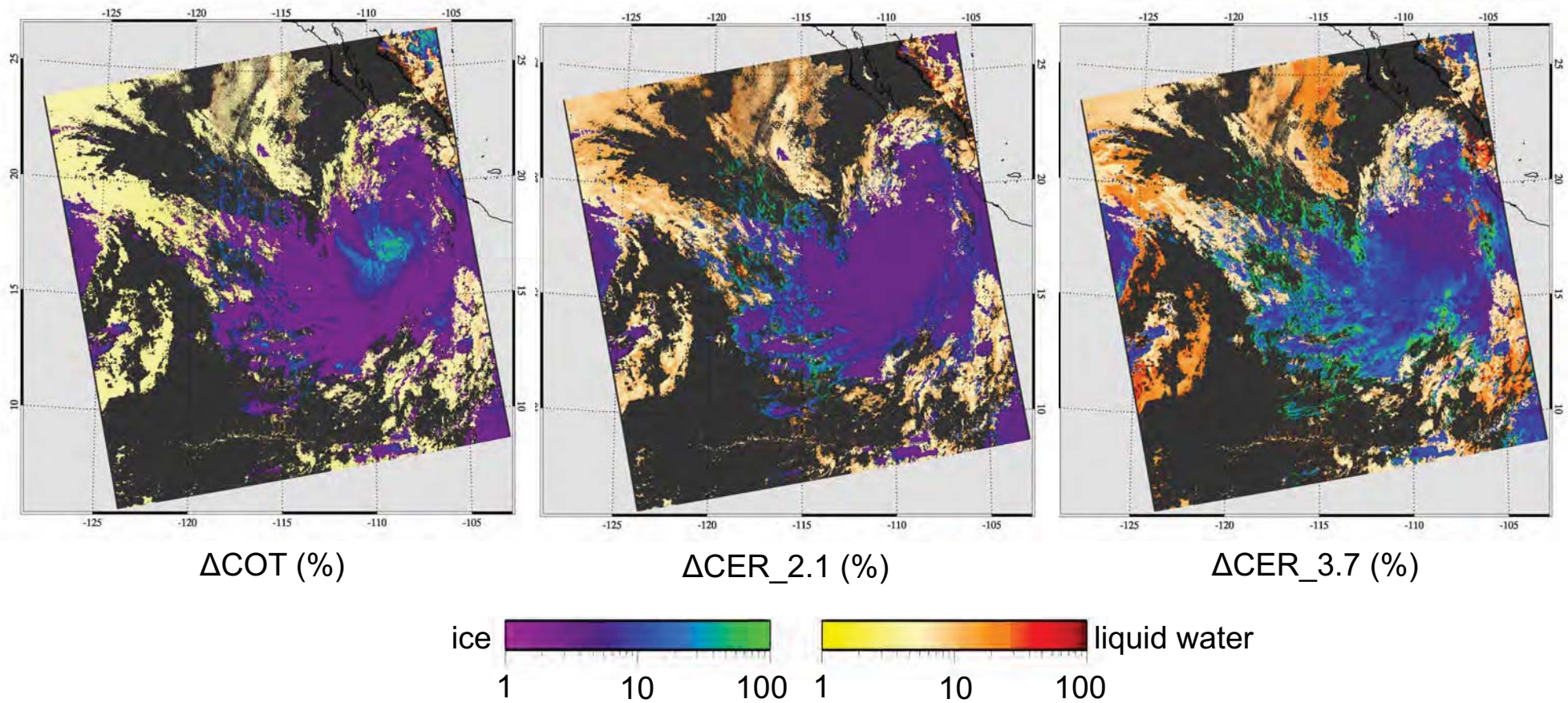


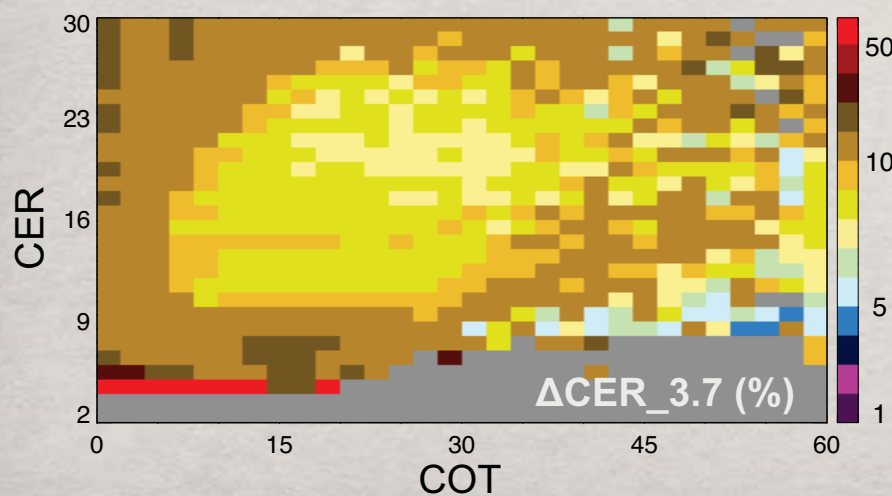
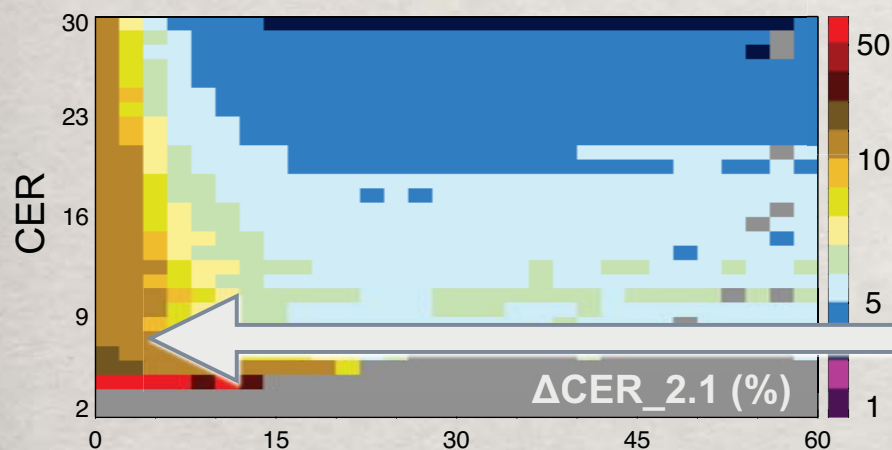
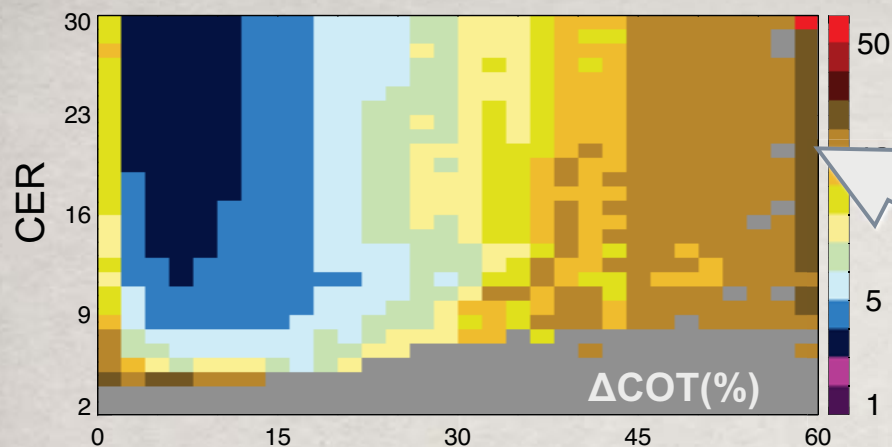
CER_3.7 (μm)



Pixel-Level Retrieval Uncertainties

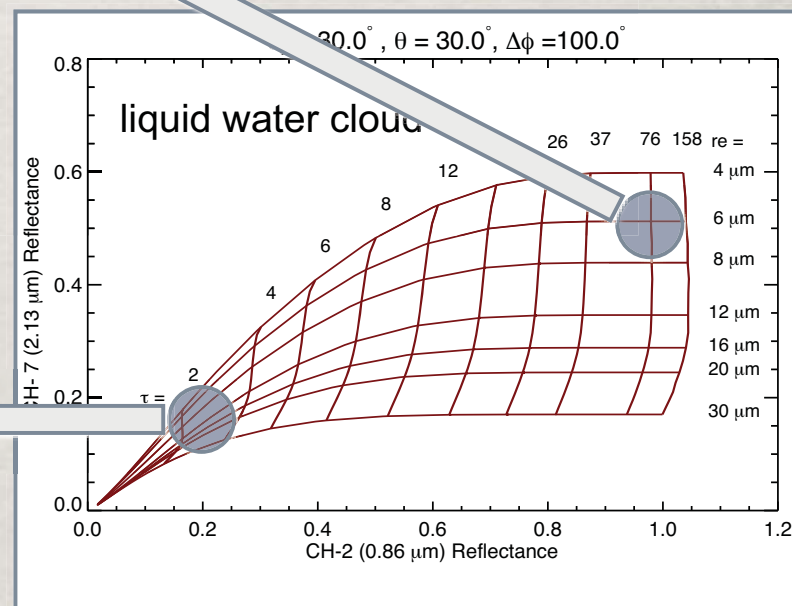
2 July 2008, MODIS Aqua C6, 2105 UTC
(best quality pixels only, CSR=0)





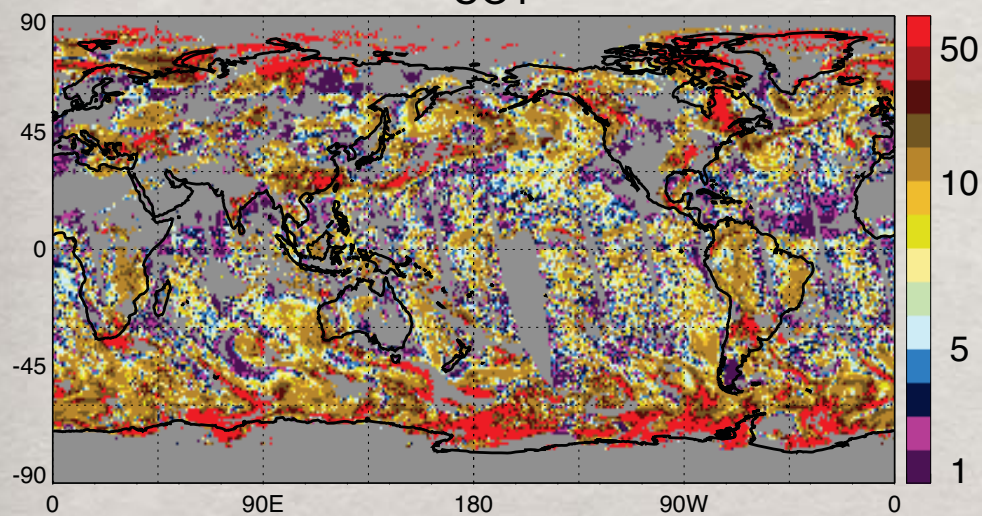
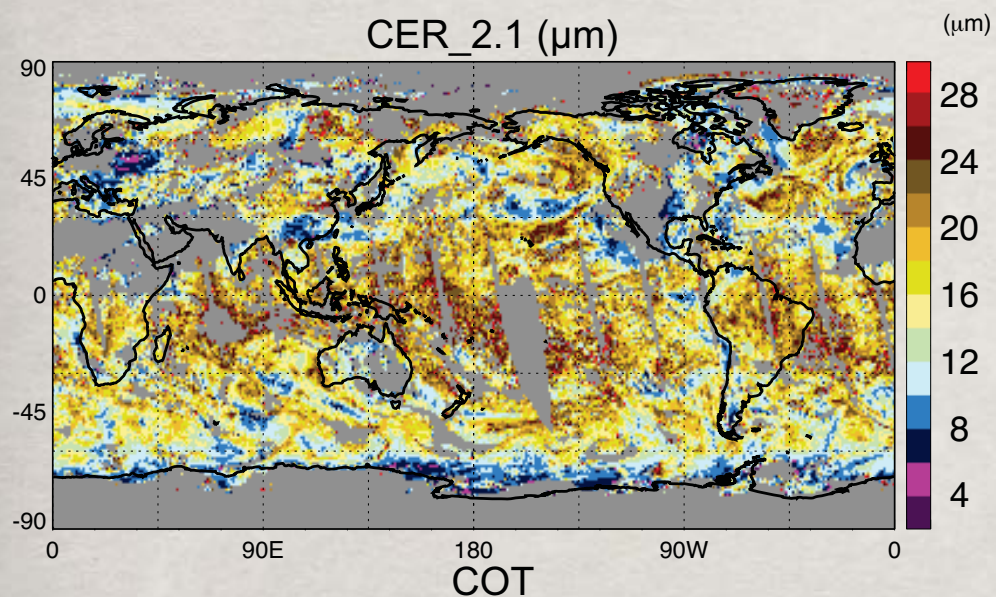
Mean Uncertainty vs. COT, CER Liquid Water Pixels

2 July 2008, MODIS Aqua



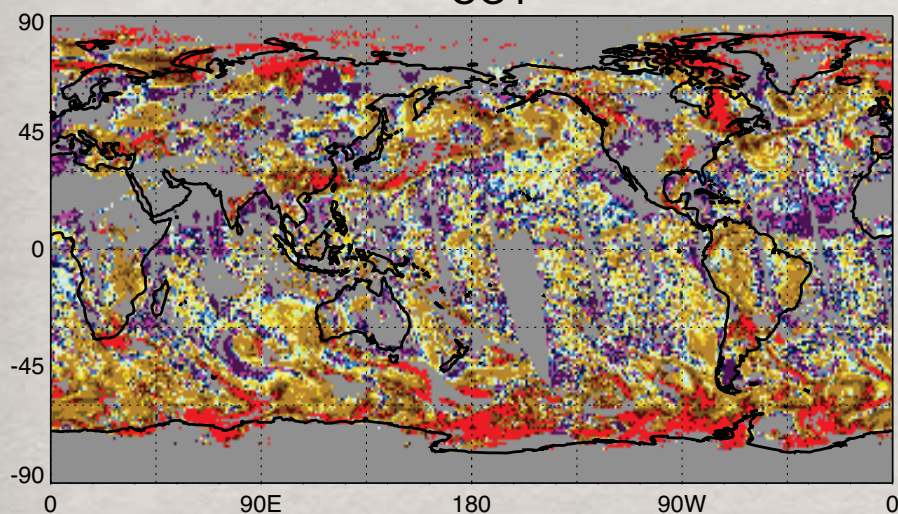
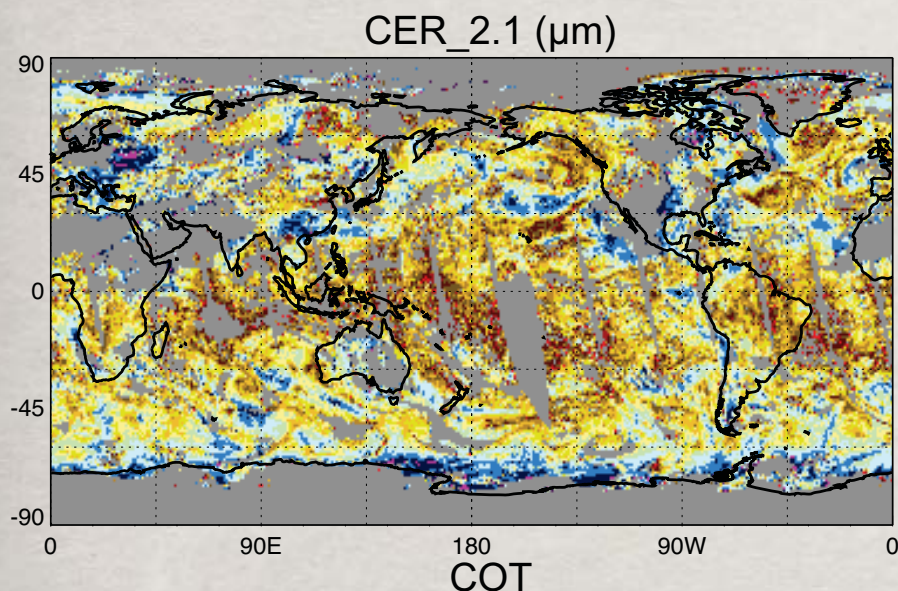
Uncertainties in Aggregated Means: Correlations?

Daily Means for Liquid Water Clouds

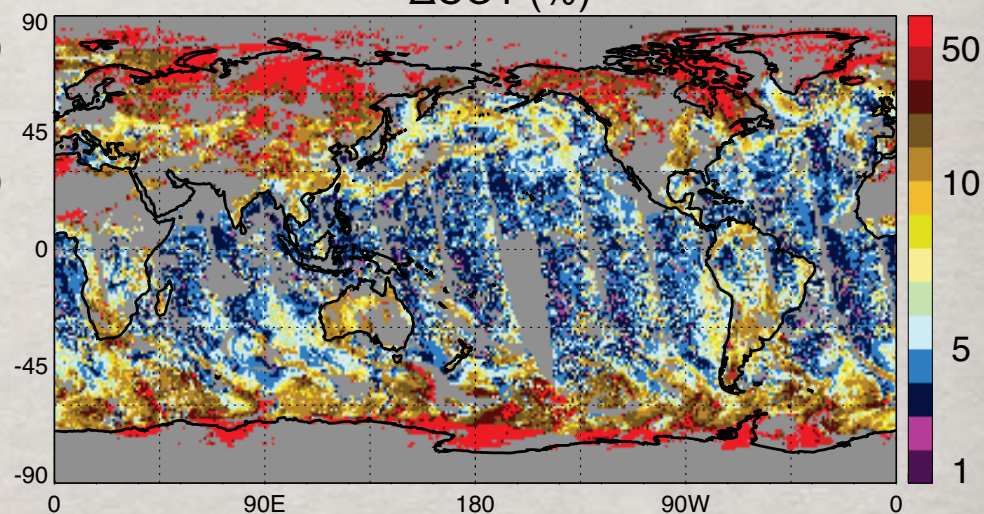
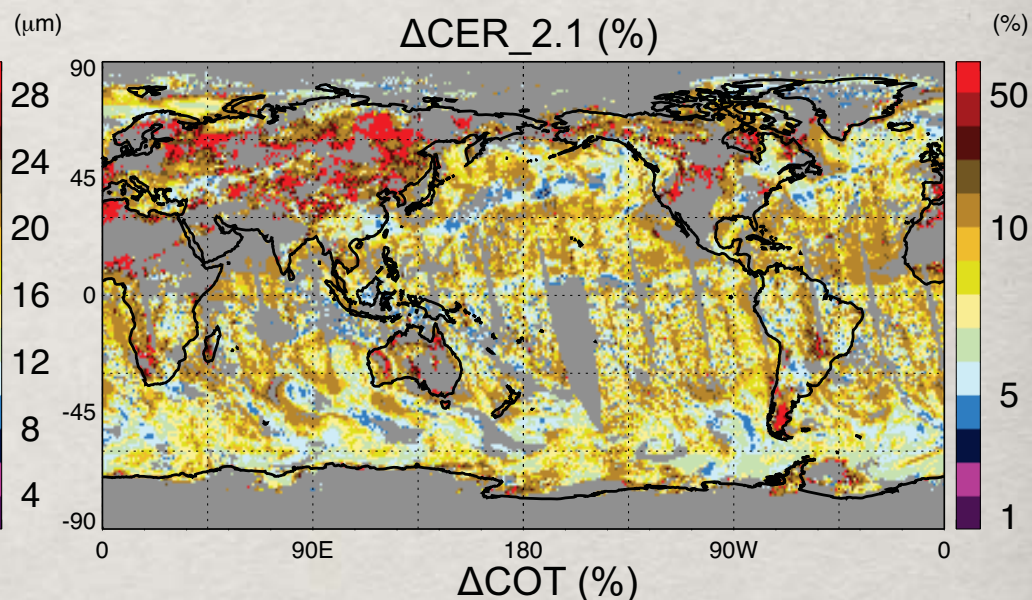


Uncertainties in Aggregated Means: Correlations?

Daily Means for Liquid Water Clouds

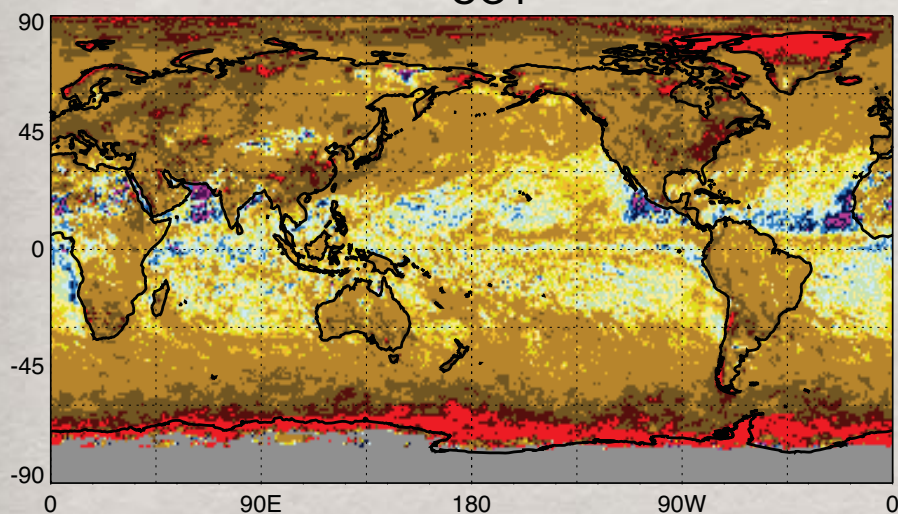
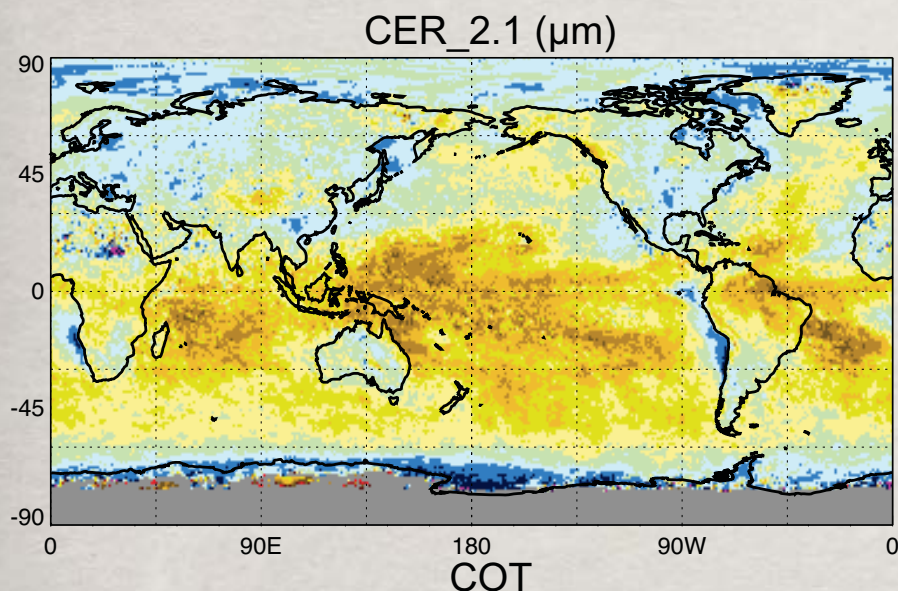


Single Day Uncertainty (1 April 2005) w/pixel-to-pixel error correlation = 1

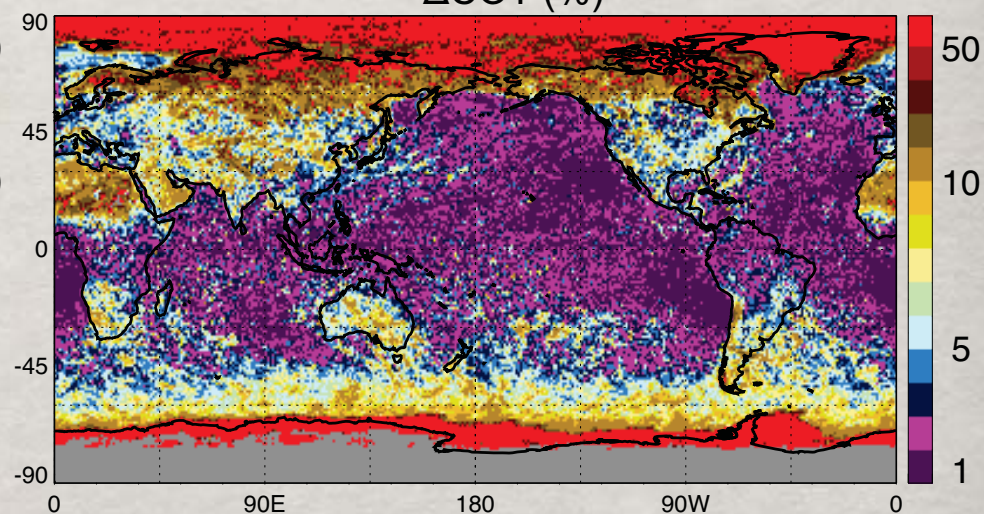
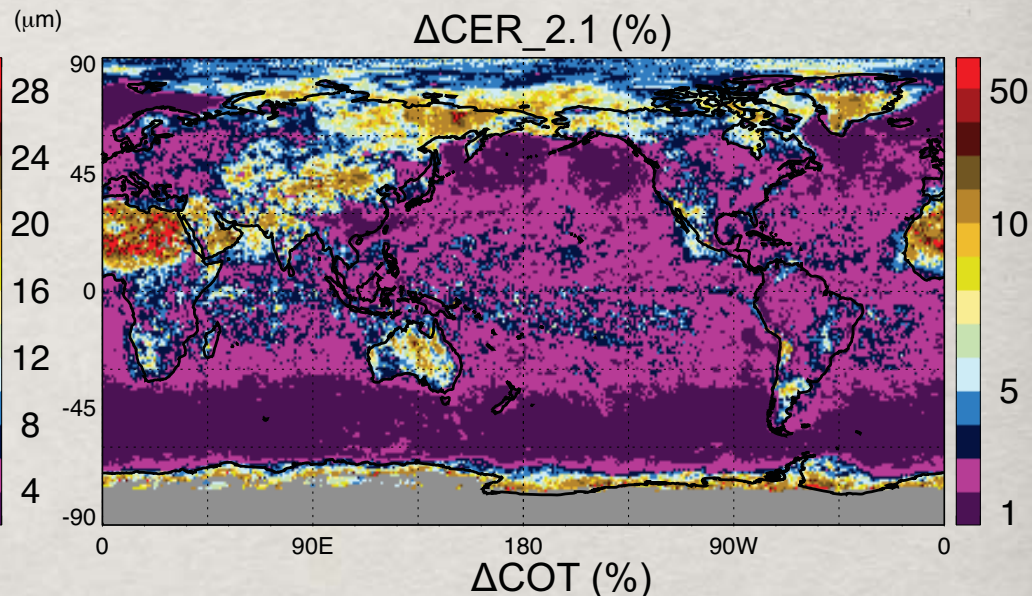


Uncertainties in Aggregated Means: Correlations?

Monthly Means for Liquid Water Clouds

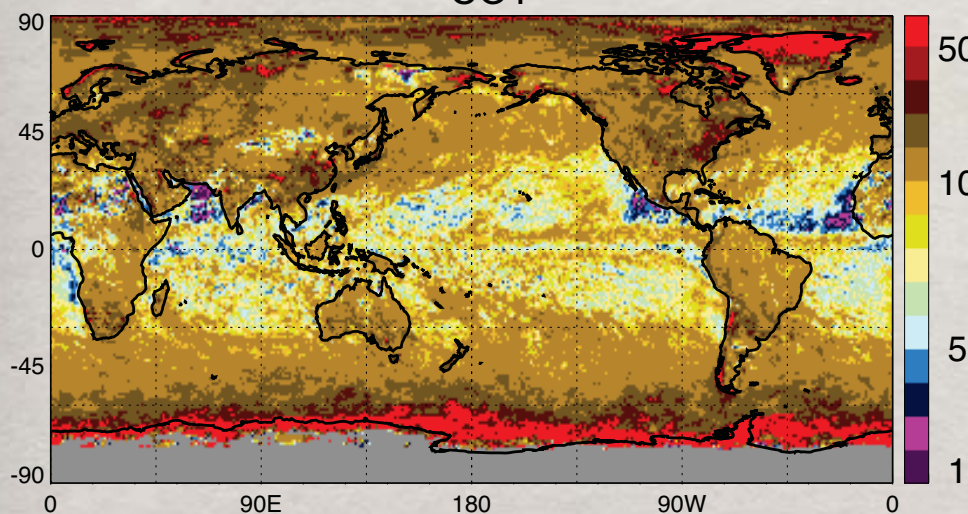
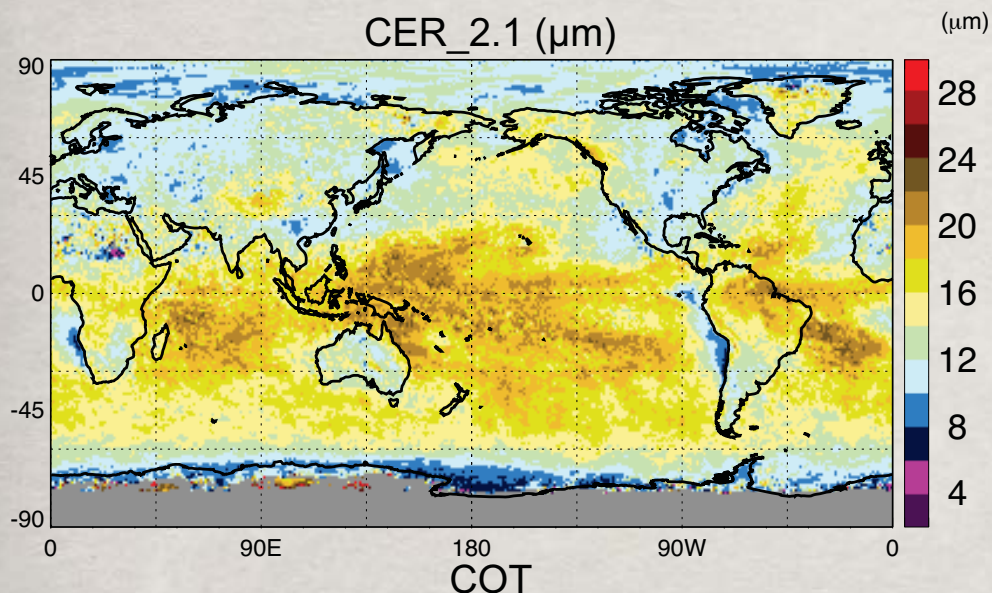


Monthly Uncertainty (April 2005) w/day-to-day error correlation = 0

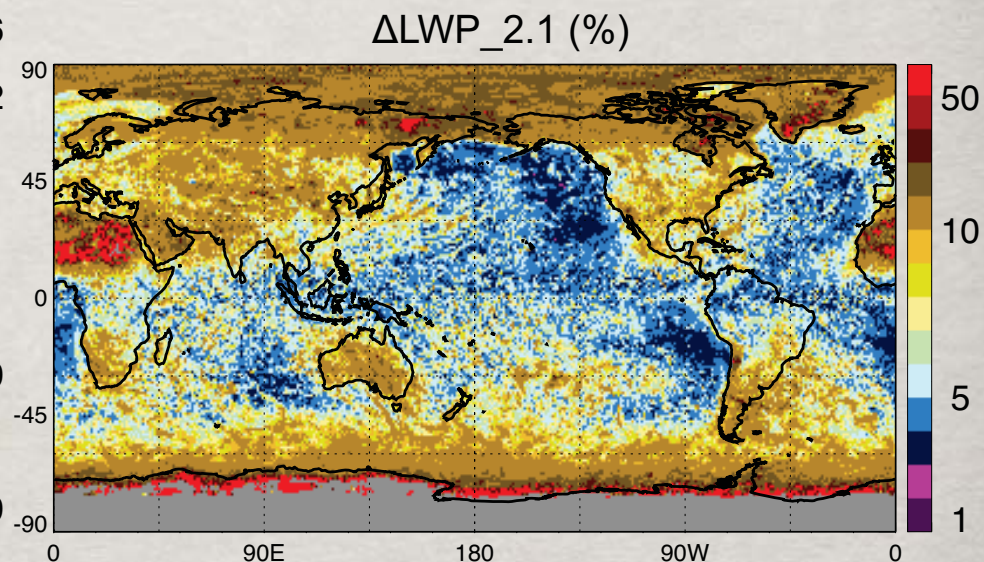


Uncertainties in Aggregated Means: Correlations?

Monthly Means for Liquid Water Clouds

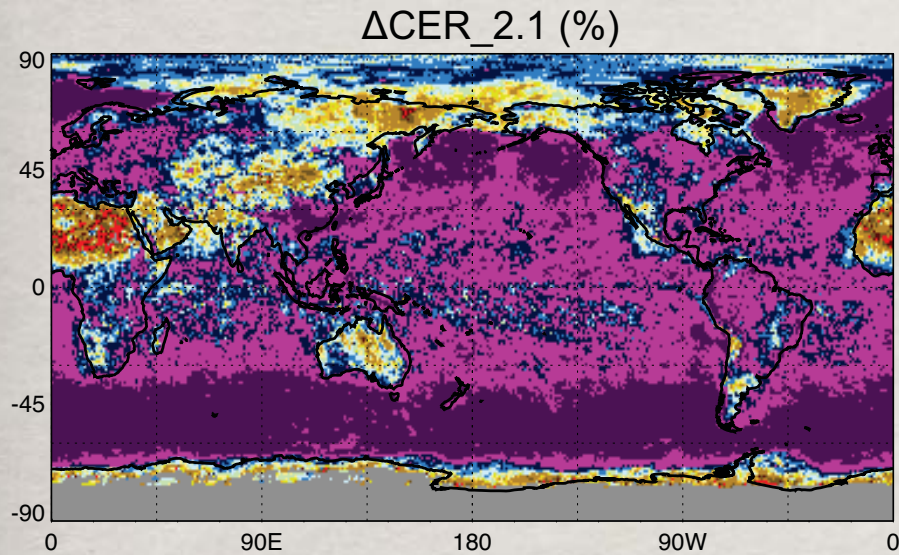


Monthly Uncertainty (April 2005) w/day-to-day error correlation = 0

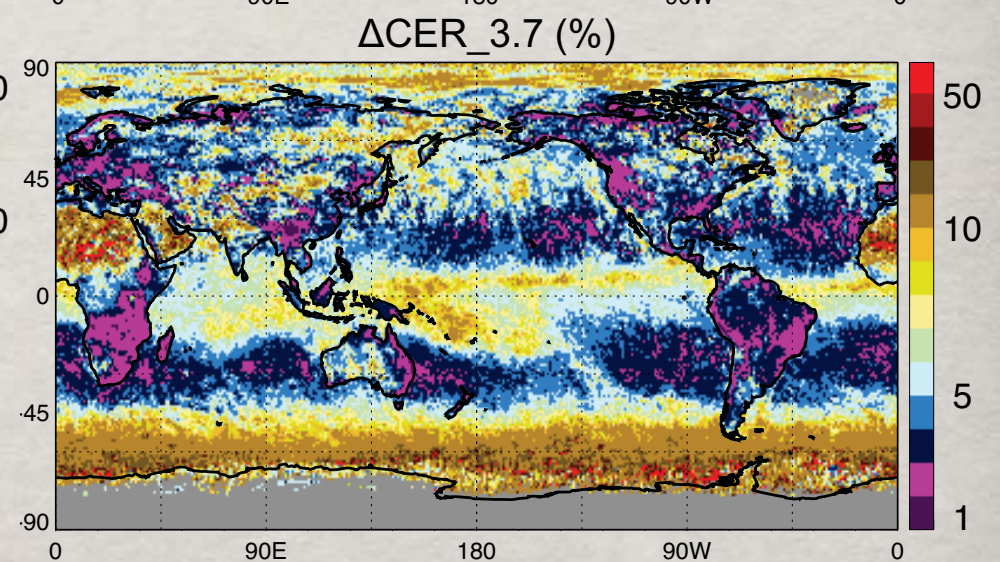
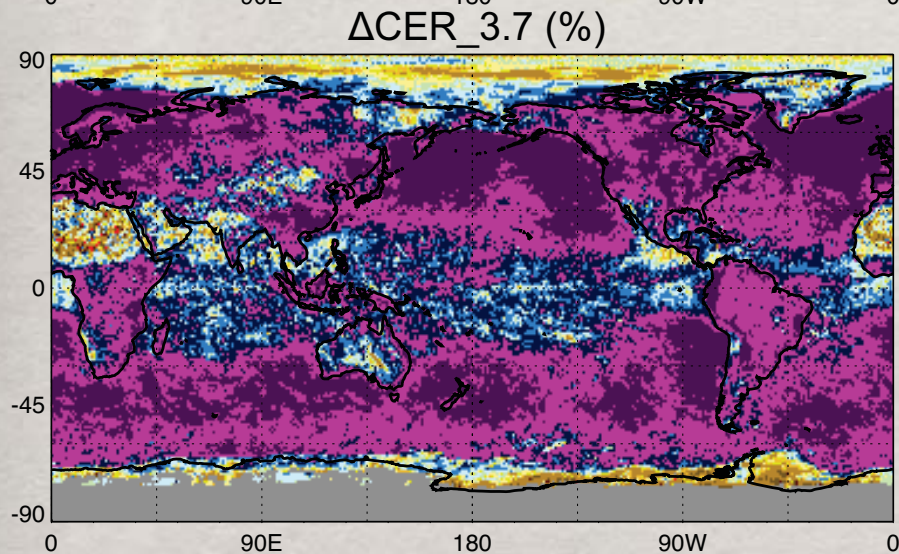
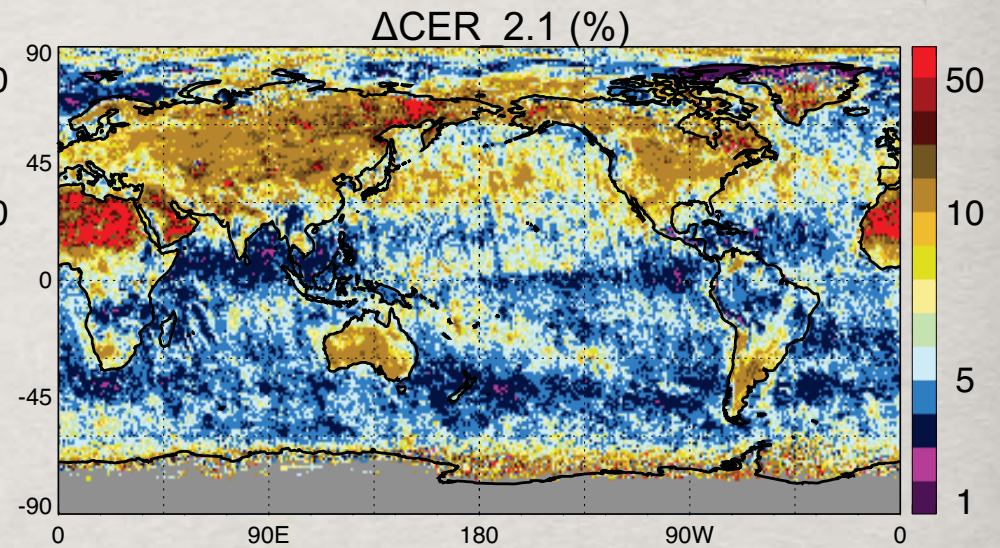


Uncertainties in Monthly Aggregated Means - Sensitivity

Monthly Unc. Liquid Water Clouds
Best Quality Pixel Aggregation



Monthly Unc. Liquid Water Clouds
“Partly Cloudy” Pixel Aggregation



Summary

- MODIS Collection 6 provides pixel-level COT, CER, and WP retrieval uncertainty estimates for the various spectral channel combinations
 - error sources: L1B spectral radiometric uncertainty assignments, atmospheric corrections (q , O_3), surface albedo/temperature, effect of temperature errors on $3.7\text{ }\mu\text{m}$ CER retrievals, limited cloud model parameters (effective variance, Cox-Munk wind vector)
- Issues:
 - How to quantify the impact of Algorithm Discrete decisions (cloud detection, phase) and Quality Assurance choices (pixel screening)?
 - Uncertainties in gridded statistics requires understanding pixel-to-pixel space/time correlations among the error sources!
- Cloud retrieval uncertainties cannot include all error sources (known and unknown unknowns) but should still be useful as a baseline estimate
- Data presented here is from the final Collection 6 algorithm. Aqua L2 reprocessing just started. Terra reprocessing will follow completion of Aqua.